Weak realignment criterion for detecting continuous-variable entanglement

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Abstract

We introduce a weaker but physically implementable version of the so-called realignment criterion for detecting continuous-variable entanglement. This criterion is weaker than the realignment criterion in the sense that we were not able to detect any bound-entangled states by using our new criterion. However, the physical implementation only requires Gaussian transformations and homodyne detection. Moreover, we improve the criterion by using a filtration method.

One of the difficult question in quantum information science is wether a state is entangled or not. Many researchers have looked into this topic because entanglement is a valuable resource in quantum information processing. Both in discrete- and continuous-variable systems, many separability criteria — i.e. conditions that are necessarily satisfied by a separable state — have been proposed. One can consult [1] for a review, but the most widely known criterion is the Peres–Horodecki criterion [2, 3], often called PPT criterion for positive partial transpose. Introduced for discrete-variables systems, it says that if a state is separable, then its partial transpose state must remain physical. This condition is generally only necessary and becomes sufficient only for systems of dimension 2×2 and 2×3. The PPT criterion was generalized to continuous variable by Duan *et al.* [4] and Simon [5]. The latter criterion is necessary and sufficient for all $1 \times n$ Gaussian states [6] and $n \times m$ bisymmetric Gaussian states [7]). In all other cases, when a state is entangled but its partial transpose state is positive, we call it a bound entangled state.

Another interesting criterion is the realignment criterion [8, 9]. Interestingly the realignment criterion has allowed the detection of some bound entangled states in both discrete [8] and continuous cases [10]. However, this criterion is difficult to compute, especially for systems of infinite dimensions. To our knowledge, it has only been computed for Gaussian states and yet, the difficulty increases with the number of modes. In this paper, we propose a weaker version of the continuous-variable realignment criterion for Gaussian states, and give a physical implementation of it. Moreover, we show that by using a filtration method it is possible to improve the criterion. This filtration can be physically implemented as a noiseless attenuation channel applied on the subsystem with highest mean photon number.

In conclusion, we propose a weak realignment criterion enhanced by a filtration procedure that offers a physically implementable entanglement criterion for continuous-variable states.

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